application
note

Instrument Landing System Receiver Testing

by David Owen

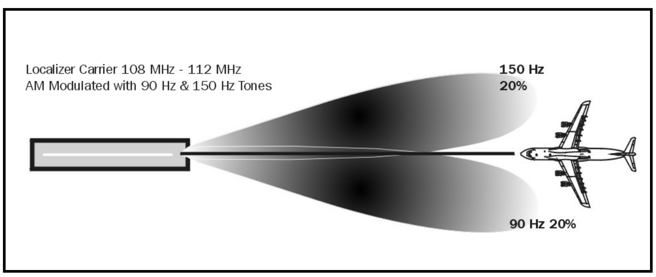
The 2030/40/50 series Signal Generators are available with Option 6, which adds an ILS (Instrument Landing System) and VOR (VHF Omni Range) waveform generator to the modulation system. The performance of this waveform generator is required to be much better than the typical characteristics of an Avionics receiver in order to reduce measurement uncertainty.

The IFR 2030/40/50 Avionics Signal Generators use a patented method of generating ILS waveforms, which considerably improves the stability and accuracy of the audio source. In addition the Avionics Signal Generator is capable of generating VOR, Marker Beacon and ADF Test Signals.

Instrument Landing System - ILS

An Instrument Landing System is used to assist aircraft as they approach the end of a runway for landing. The system has two parts - the Localizer that controls the horizontal alignment and the Glidescope that controls the angle of approach. The Localizer and Glidescope operate at different carrier frequencies.

From the aircraft receiver perspective, each part of the landing system uses two transmitters operating at the same frequency. One transmitter generates a carrier frequency that is AM modulated with a 90 Hz tone. The other transmitter generates a carrier frequency that is AM modulated with a 150 Hz tone. As shown in Figure 1, the transmitters are arranged to produce beams that overlap. Beam shaping at the transmitter is produced using an antenna array.



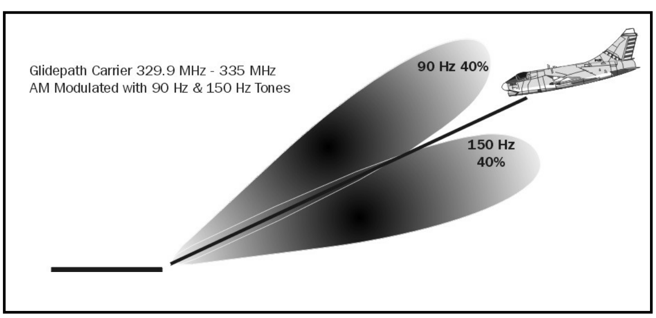


Figure 1 - Localizer and Glidescope systems of ILS installation

The ILS receiver of the aircraft detects both the 90 Hz and 150 Hz AM components of the signal. When the AM depths of the two tones are equal the aircraft is aligned with the runway and is said to be "ON COURSE".

When emulating the ILS signals detected at the aircraft receiver input, it is essential to have good Difference of Depth of Modulation (DDM) accuracy, since any error will result in the aircraft receiver showing misalignment with the approach path.

ILS Waveform Generation

As stated previously an ILS Localizer or ILS Glidescope waveform requires two tones to be generated - one at 90 Hz and the other at 150 Hz. The relative phase of the tones is fixed by ICAO standards and the frequencies of the tones result in a composite waveform whose shape repeats at a 30 Hz rate. The magnitude of each tone must be controlled such that the arithmetic Sum of Depth Modulation (SDM) of each tone is constant and the DDM between the two tones can be varied in a precise manner.

DDM can be expressed either in terms of percentage (%) or as a modulation index. A DDM of 1% is equivalent to 0.001 DDM. In this article, DDM will be expressed in terms of modulation index.

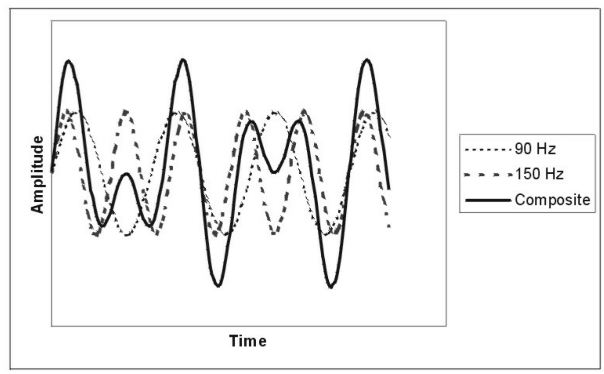


Figure 2 - ILS waveform with 0 DDM

Using Direct Digital Synthesis (DDS) techniques it is simple to generate two tones whose relative phase is controlled to the requirements of the ICAO standard. However, to provide fine control of the DDM requires great accuracy in the control of the level of the two tones. Furthermore, if the two synthesizers generating the tones exhibit small differences in stability with time or temperature the effect on the accuracy of the DDM can be dramatic.

As an example, consider the situation where two DDS's are used to generate an ILS waveform. If a 12 bit DAC (digital to analog converter) is used to control the audio output level of each tone the level control has a resolution of approximately 1 part in 4000. Assuming full scale is arranged to represent 100% AM depth then the DAC level resolution is 0.025% depth. In order to keep the SDM constant for every 0.025% increase in the depth of one tone the other tone depth has to be reduced by 0.025%. In other words the DDM resolution in this case is 0.0005 DDM. Taking into account that a real DAC is never perfect the implication is that to provide good DDM control and accuracy using two independent sources 16 bit of level control resolution is required.

The problems are potentially even more serious if stability is taken into account. If a stability of DDM of say 0.0001 DDM is required over a temperature range of ±20°C then each audio channel will be required to have a stability of 0.005% or 5 in 10^5. Over a temperature range of 20°C this represents a temperature coefficient of 2.5 in 10^6 per °C. This is not easily routinely achieved.

For this reason IFR has not used this method in implementing the Avionics version of the signal generator. Instead a method has been patented which virtually eliminates many sources of error. The method used also ensures that the required waveforms can be generated using relatively non-critical parts. The technique makes use of the fact that a DDS can be used to generate any repetitive waveform that can be stored in a look up table. The ILS waveform repeats at a 30 Hz rate so one of the waveforms generated is an ILS waveform that has 0 DDM present. As a result since both tones are sent through the same level control circuits, provided these circuits are linear and have adequate bandwidth (a relatively easy requirement), any changes in gain in the circuits have no effect on the DDM. Consequently a 0 DDM signal can be generated which is very precise and stable. Provided the correct look up table is installed there is very little that can go wrong in the waveform generator.

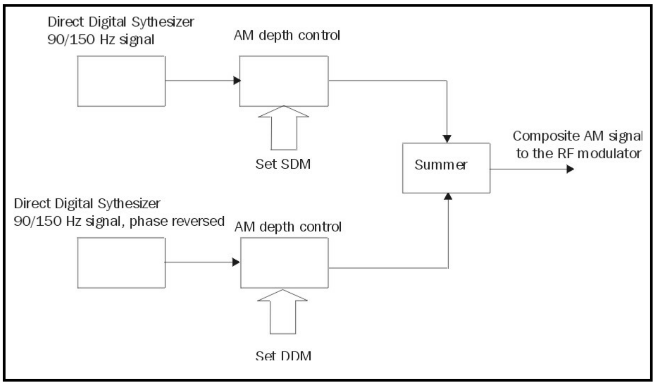


Figure 3 - Simplified schematic of the modulation drive system used in Option 6

In practice however, waveforms need to be generated which have a non-zero DDM. In principal the look up table could be computed and re-loaded for each requirement. However the DAC used in the DDS would need fine resolution, and computing the waveform and loading it each time would not be convenient. Computing the waveform in a DSP is possible, but there are still D to A converter issues and the problem of validating the DSP code under all conditions. The method adopted for the 2030 Avionics Signal Generator is to generate a second ILS waveform with 0 DDM, but with the relative phase of the 150 Hz tone reversed compared to the 90Hz tone. A small amount of the signal generated from this reversed source is added to the 0 DDM source. If a DDM of 0.001 DDM is required then the signal from the reversed source is added at a level corresponding to 0.05% AM depth. The two 90 Hz tones add in amplitude but because the 150 Hz tone is phase inverted the 150 Hz tone subtracts and consequently the tone depth is reduced. As a result a DDM of 0.001 DDM is produced.

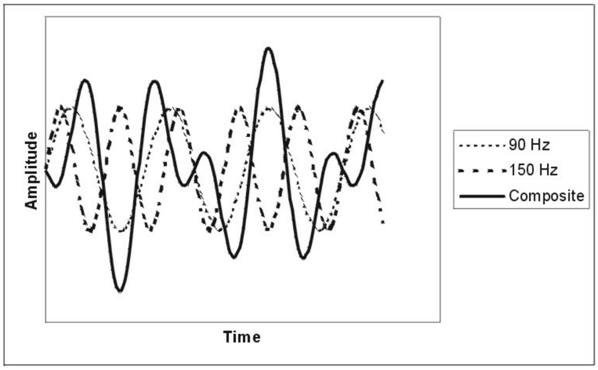


Figure 4 - ILS waveform with the phase of the 150 Hz tone shifted by 180° compared to Figure 2.

The advantage of using this technique is that introducing the phase-reversed signal can easily control the DDM. The stability of the reversed signal has little effect on the accuracy of the resulting signal when small DDM settings are requested since the amount of reversed signal used is small. The resolution problem of the DAC's are also greatly eased because for small DDM the level of the reversed signal can be reduced using a simple attenuator before it is added to the 0 DDM signal.

VOR System

The VOR system is designed to provide bearing information for the aircraft from the VOR transmitter. By using more than one VOR transmitter the position of the aircraft can be derived. Modern VOR transmitters transmit a carrier with a 30 Hz AM tone. At the same carrier frequency a second AM tone is produced at 9.96 kHz whose frequency is modulated by ±480 Hz at 30 Hz rate. The phase of the 30 Hz AM tone and the 30Hz FM tone on the 9.96 kHz sub-carrier are compared to derive bearing information of the aircraft from the beacon.

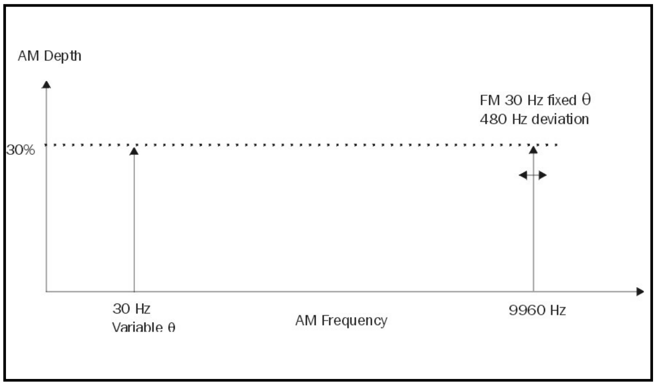


Figure 5 - Modulation Spectrum of a VOR Signal

VOR Generation

To simulate VOR signals a source is required that generates a 30 Hz tone and 9.96 kHz sub-carrier with 30 Hz rate frequency modulation superimposed on it. The phase of the frequency modulation and the 30 Hz tone are controlled to give the required bearing information. This would normally require the 9.96 kHz oscillator to be frequency modulated. Although this can be done, it is not an easy task and IFR has used a solution which is much simpler and less prone to errors.

Again use is made of the fact the sub-carrier waveform with its frequency repeats at a 30 Hz rate. A DDS is used which uses a look up waveform that contains a complete cycle of the 30 Hz FM signal on the 9.96 kHz sub-carrier. The second DDS generates a simple 30 Hz tone and the two signals are combined to form the composite AM signal. To control the bearing setting the relative phase of the two sources is controlled by the microprocessor using timers to generate the required phase control. Since this can be simply done using digital electronic circuits the use of analog frequency modulation can be avoided.

Testing avionics performance

The method used for generating the avionics waveforms also considerably simplifies the task of assessing the performance of the signal generator when it is in service. The test procedures simply require that the key AM performance specifications (accuracy, distortion and bandwidth) are met and that the ILS or VOR mode is generating the correct waveforms.

In the case of ILS, 0 DDM values use just one of the DDS waveforms and as the DDM is increased more of the second waveform is introduced. Ultimately when the DDM is set to be equal to the SDM only one tone (90 or 150 Hz) should be present.

This gives the user a high confidence that the signal generator is performing correctly without the use of expensive specialized equipment.

2030/40/50 performance

The 2030 based signal generators have excellent AM performance. The AM is generated using envelope feedback techniques and a high performance amplitude modulator which provide excellent AM accuracy and stability. The linearity of the AM system is optimized during calibration to ensure that the AM system has very low distortion. The envelope feedback system has a BW of typically 100 kHz or more in the avionics bands, ensuring that there is little phase error introduced between the 90 Hz, 150 Hz tones for ILS systems and the 30 Hz, 9.96 kHz tones in VOR. Changes in environmental conditions have a negligible affect on AM performance, giving the user confidence in the signal generator output under all conditions.

The generator provides the user with very low residual DDM error, conservatively specified at just 0.0003 DDM.

Other Avionics Options

The 2030 series signal generators can also be supplied with options configured to aid the testing of DME systems. Option 9 adds an internal pulse generator that can be used to drive the Option 10 DME system. The DME (Distance Measuring Equipment) allows the user to generate Gaussian shaped pulses for stimulating DME receivers.

Applications

The avionics options on the 2030/40/50 series are used extensively in avionics and associated industries. The 2030 is used extensively for checking airfield ILS monitor systems to make sure the automatic alarm systems are working correctly. The signal generator is also used to check the calibrated receivers used in aircraft that perform flight inspection tests of ILS installations.

Manufacturers and aircraft workshops use the 2030 series to check the performance of aircraft ILS, VOR and VHF radios. In manufacturing the excellent accuracy of the RF output signal ensures that the 2030 series signal generators meet even the most demanding applications.

The 2040 series when fitted with avionics options provides very low noise signals that can test the selectivity of the aircraft receivers in the presence of other signals. The low phase noise of the 2040 series ensures the test results are not influenced by limitations in the signal generator noise, particularly at offset frequencies of between 6 kHz and 30 kHz. As the aviation frequency bands become more crowded the performance level required of both the navigation receivers (ILS, VOR) and the radio systems become more critical, making it essential that adjacent channel rejection and blocking tests are performed.

The 2050 series signal generators are capable of generating signals conforming to the VDL standards with low levels of adjacent channel power, extending the application of the generator to digital avionics receivers.

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